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Multipactoring in a Positron Storage Ring

The kinetic energy acquired by a free electron during the passage of a positron bunch depends on the initial transverse location of the electron. To simplify the calculation, it is assumed that the bunch is cylindrical (length ℓ, radius a) and that the electron is initially at rest and at a radial location $r_i < a$. With these assumptions, one finds the electron kinetic energy

$$E_{kin} = \frac{e \hat{I} Z_o}{4\pi} \left(\frac{r_i^2 - r_f^2}{r_i^2}\right) \qquad (1)$$

where $\hat{I} = \frac{2\pi R}{m_b \ell} I$ = bunch current

$2\pi R$ = ring circumference

m_b = number of bunches in the ring

I = average current

r_f = final radial location of the electron in the positron bunch

Z_o = 120 π ohm

From Eq. (1), one sees that the maximum kinetic energy is obtained by an electron with $r_i = a$ and $r_f = 0$. Assuming $a = 2.5 \times 10^{-4}$ m, $\ell = 2 \times 10^{-2}$ m, $m_b = 50$, $I = 0.1$ A one finds for $2\pi R = 800$ m, $\hat{I} = 80$ A and $E_{kin} < 2400$ eV.

Multipactoring can occur if the following two conditions are satisfied:

1. The electrons must arrive at the vacuum chamber wall with sufficient energy to produce a secondary emission coefficient δ in excess of unity.
2. The transit time of an electron between the vacuum chamber surfaces must be equal to the bunch period or a multiple of it.

The secondary emission coefficient δ depends on the material and the state of the bombarded surface. It is higher for smooth than for rough surfaces. The time between the arrival of the primary electron and the departure of the secondary electron does not exceed 10^{-12} sec. For a vacuum chamber with a full aperture d, the transit time is approximately

$$\tau_t = \frac{d}{2v_p} + \frac{d}{2v_s} + \frac{\ell}{c},$$

where v_p = velocity of the primary electron

v_s = velocity of the secondary electron

For relatively clean metal surfaces, the energy of the bombarding electrons must exceed 100 eV ($v_p > 5.93 \times 10^6$m/sec) to produce a secondary emission coefficient δ in excess of unity. Most of the secondary electrons have an energy of the order of 10 eV ($v_s = 1.88 \times 10^6$m/sec). Setting $d = 6 \times 10^{-2}$ m, $\ell = 2 \times 10^{-2}$ m, one obtains the transit time $\tau_t < 4.21 \times 10^{-8}$ sec. Therefore, with the number of bunches in the ring $m_b < 50$ (bunch period $\tau_b > 5.3 \times 10^{-8}$ sec) it is not likely that multipactoring will occur.